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THE AUSTRALIAN MINE SWEEPING GAME

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DSTO

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Abstract

This Note describes the Australian Mine Sweeping Game (AMSG). The game represents minesweeping and enables MCM officers to become more familiar with the consequences of various sweeping tactics. The game is designed for a single Player (or a team of Players working together) and an Umpire. The Umpire can lay a minefield, selecting mines from a list of five types. The scene can be set for the Players, and their performance monitored. The Players appraise the situation, and then devise the tactics for sweeping the minefield. Hints are provided on likely mines in the field. The game will show the Players how effective the tactics they chose proved to be, by showing a simulation of the minefield being swept.

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The Australian Mine Sweeping Game

1. Introduction

The Australian Mine Sweeping Game (AMSG) was written, and in this work, adapted, to enable those with an interest in Mine Countermeasures to test their skills at inferring conditions in a partially understood minefield clearance situation, and at setting the tactical parameters for sweeping the minefield. The aim of this paper is to document the game formally, and to act as a user manual.

The game may be used to see how successful the tactics chosen would be in clearing the minefield. It may also be used to explore alternative tactics settings for any improvement in operational effectiveness. Alternatively, the game may be used as a means for improving understanding the tactical requirements for sweeping of a minefield.

AMSG makes no claim to great depth of insight into minefield sweeping, nor can it solve problems for the player which cannot be solved with a good understanding of MCM doctrine. On the other hand, the game does represent many of the main performance variables covered in more sophisticated models, and can be used by any officer on a personal computer.

1.1 What is AMSG?

The AMSG, is designed to be played by mine warfare officers as a means of visualising the consequences of variation in the basic parameters underlying Mine Sweeping doctrine and tactics. The AMSG can be used as a training aid in a structured or a non-structured way, or as a means of conducting exploratory tactical studies.

AMSG is a simple simulation of the Mine Sweeping operation. It is designed to be used by one Player, possibly with an Umpire setting the scene. In this paper, the program is described as if it were being used by a Player and an Umpire. In practice, the Player may perform all the Umpire's functions. Player access to umpire functions can be disabled by changing a password.

The Umpire:

sets the regional map to be used,
delineates the area of the map to be mined,
chooses the mine type(s) to be laid from the available five types, and
lays the mines in the field.

The Umpire then monitors the performance of the Player in :

assessment of the Sweep and Sweeper parameters,
assessment of the minefield situation, and
use of these assessments to decide on appropriate Mine Sweeping tactics.

The game allows these tactics to be played against the Umpire's minefield to demonstrate the effectiveness of the tactics and parameters chosen by the Player. It is able to show when assets such as Sweeps or Sweepers (MCMVs) are damaged by mines, as well as to show the clearance levels the Player achieved.

AMSG is suitable for fundamental training and instruction in the principles of Mine Sweeping. It assumes that the player has a working knowledge of Mine Sweeping doctrine, and is capable of determining the tactics to be deployed against a minefield. At a minimum, the Player is expected to be familiar with the mine warfare concepts covered by the NATO ATP-6 document [1].

2. *Design of the Game*

The AMSG is "menu driven" (a graphic of the menus is at Figure 1). Help is available from every Menu. By selecting HELP in a menu the User is given more details about each of the selections available from that Menu. A copy of the Help files is given at Appendix A.

The game comprises a minefield containing one or more types of mine, a mine Sweeper (or Mine Counter Measures Vessel, MCMV), and a Sweep. The Sweep is used to produce the emulation of the magnetic and acoustic fields of a target vessel. It is defined by the parameters A (actuation width) and B (actuation probability). A mine's effect on the Sweep or the Sweeper, once actuated, is determined by F (damage front) and BF (damage probability). The Sweeper (MCMV) and Sweep move together through the minefield, with the same speed and navigation error, but separated by the tow distance.

2.1 Operation of the AMSG

A minefield is laid by the umpire, by selecting the UMPIRE SETTINGS option in the Main Menu. Alternatively, the player can load a previously set minefield from the OPTIONS choice. All preset minefields have the file extension MFD. See Section 4.3 for more details on how the Umpire sets the minefield.

The Umpire can select a map from a library supplied, or can draw a new map using the mouse (see Appendix C).

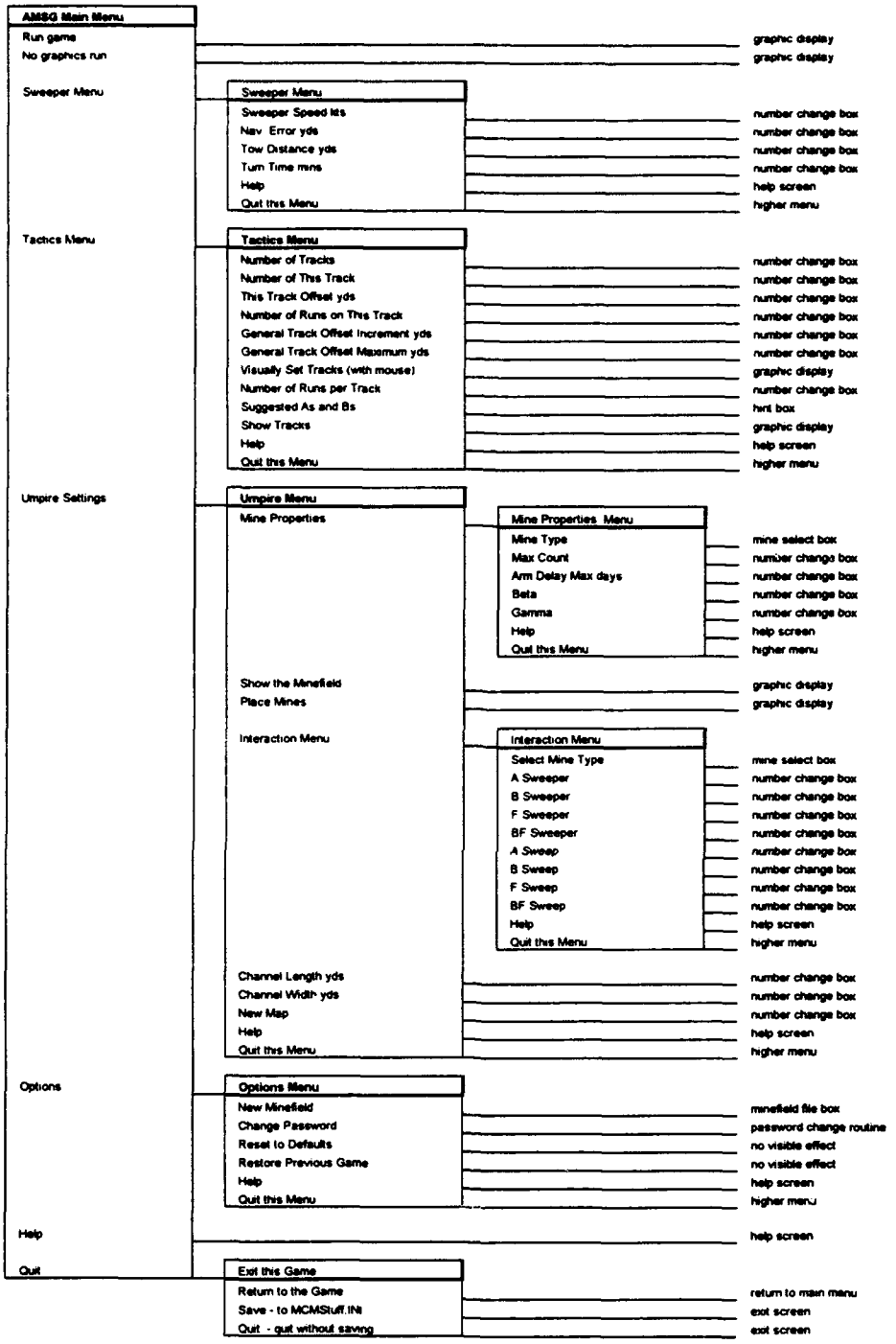

Figure 1: *AMSG Menu Structure. Menu Titles are in boxes. A menu item can call the menu title shown to the right of it, or a number box, a help screen or a graphical display, etc as shown on the far right.*

The minefield is laid in a zone within the map, selected by the Umpire. This zone is defined by drawing two vertical lines, with the mines being then laid between these lines. The centre of the channel is always set as the centreline of the map, though it is up to the Umpire where the mines are laid. The Umpire may choose to lay them across the centre line, or anywhere else within the vertical lines.

The minefield may comprise one or more mine types. The Umpire can select mine types from a menu. Up to five different mine types can be laid in a single minefield, though a minefield is limited to a maximum of thirty mines.

The locations and types of the mines are displayed to the Umpire while they are being set, and are thereafter concealed. When the game is played, the locations of mines can be revealed in one of several ways. Firstly, if mines are swept by the Sweep, they are displayed as an 'Explosion'. If a mine damages the Sweep itself, the location is marked by a 'Broken Sweep' symbol, if a mine damages the MCMV, the location is marked by a 'Sinking Ship' symbol.

In the cases of a damaged Sweep or Sweeper, the game continues. That is, it assumes that replacement equipment is readily available. This approach gives the Player an overall indication of the effectiveness of his/her tactics choices, and other settings.

The Player must estimate the Sweep/Sweeper tactics. The usual way to do this is by estimating mine/target actuation width and probability of actuation (A and B, respectively, in NATO terminology[1]) and the damage front and damage probability (F and BF) . Given these values for the Sweep, and the similar figures for the Sweeper vessel, he/she then uses his/her expertise, such as that provided by [1], to set the Sweep tactics, namely the distance between tracks, D, and the number of runs per track, J. This is done by selecting the Tactics Menu, and selecting the desired values. (Note that distances are all in yards.) The values of F and BF can be used to estimate the risks associated with the chosen tactics.[1]

The Tactics Menu contains a number of options for setting the tactics parameters. These are explained in detail in Section 4.5.

Some MCMV parameters must also to be set by the player prior to starting the simulation. These are selected from the choices available in the Sweeper Menu. The parameters which may be set are :

Sweeper Speed (kts)
Navigation Error (yds)
Tow Distance (yds)
Turn Time (mins).

When all the settings that the Player chooses to make are complete, the game can be started. From the Main Menu, simply select RUN GAME. The map will be displayed, and the Sweeper (MCMV) and Sweep will be seen moving along the tracks defined by the player. Exploded mines and damaged equipment will be shown as they occur. Data on the Sweeper location, the numbers of mines swept, and the numbers of vessels and sweeps damaged is displayed, along with an estimate of the effort remaining. The track count, elapsed time and navigation error are also shown, as are the sweep speed and tow distance settings.

[1]The method by which the tactics are determined is wholly up to the Player. The game does not require the Player to provide values for A, B, F, BF or the clearance or risk estimates.

At the completion of the game, the Umpire can examine the Player's performance by entering the Umpire Settings Menu and displaying the minefield. This is done by selecting SHOW MINEFIELD . The mines, both exploded and unexploded will be displayed on the map, along with the game statistics.

2.2 *The Umpire's Role*

The Umpire performs a number of roles. Firstly, the minefield itself is set. This includes :

deciding the minefield location,
determining the channel length and width,
resetting mine properties (mine count, arm delay) if needed (see Section 3.3),
setting A, B, F and BF for each mine type, for interactions between both sweeper and mine and sweep and mine,
deciding the types of mines to lay, and
placing up to 30 mines in the minefield.

The Umpire can store the settings for later use as a datafile, or hand the game over to the Player.

The Umpire should present an oral or written 'scenario' to the Player, from which he might be able to infer roughly what types of mines might be in the field, and what is the objective of the minelay. The Player has to use this background information to determine the parameters he needs to set to play the game.

At completion of playing the game, the Umpire can evaluate the Player's performance, by selecting SHOW MINEFIELD from the Umpire Settings Menu. He will have displayed the state of the minefield, showing all mines, both activated and un-activated. The performance statistics are also shown, indicating the number of mines swept, the number of Sweepers lost, and the number of Sweeps lost. He also sees the mines which were not swept at all.

Access to the Umpire Settings Menu is only possible via a six character password. The Umpire may reset this password from the Options Menu. The old password must be given in order to specify a new one. Three chances are given to provide the correct password before the menu selection is aborted. The Player is not given access to the password.

Players can be scored in a number of ways. For example, one point for every mine correctly swept, but penalise five points for every Sweeper lost, and two points for every Sweep lost. The score could also be penalised one point for every mine not swept along the desired channel width.

The last penalty would vary according to the objective. If the entire minefield is to be cleared, then all mines laid would count, while, for example, if only a channel of width 600 yds is to be cleared, then only mines uncleared in this zone would count.

Alternatively, a simpler scoring method might be to simply fail the Player if he/she loses an MCMV, and to award a pass the Player otherwise.

2.3 *The Player's Options*

These have been broadly covered in Section 2.1. The Player is able to set all parameters which are normally under control in a real mine sweeping operation, e.g. with AMASS[2]. The Player should set all the parameters in the Sweeper Menu and then in the Tactics Menu.

The Player sets the Sweep and Sweeper parameters by means of the Sweeper Menu. The parameters here are :

Sweeper speed (kts)
Navigation Error (yds)
Tow Distance (yds)
Turn Time (mins).

All these parameters are in common to both the Sweep and the Sweeper or MCMV.

For setting the tactics, the Player should be able to make parameter selections based on the situation given by the Umpire. The game itself has a facility for providing a rough alternative, however. By choosing SUGGESTED As AND Bs in the Tactics Menu, the player can get hints of a likely mine type present, and the values of A and B which might be expected. (These hints do not imply that other mine types are not also present, though.)

To make the hints the game selects one of the mine types which has been set. Normally this will be the most numerous type in the field, but where no type is more common, one of the most common types is chosen. An approximation for the values of A and B for this mine is then made. This is done by randomly selecting a value from a Normal Distribution with a mean of actual value, and with a standard deviation 10% of the mean. No indication is given to the Player that other mine types may be present, though they may be.

After making an appreciation of the minefield, the Player should make use of a process such as that given in ATP-6 [1] to determine his/her tactics (track spacing and runs per track). He should set these in the Tactics Menu.

Provided that realistic parameters have been set, the Player should now be able to run the game and successfully clear the minefield without any loss of assets.

3. *Methodology*

This section covers the way that the AMSG sweeping simulation works.

3.1 *Encounters*

The approach to determining whether encounters have occurred is driven by the need for rapid processing of the encounters during the simulation. Therefore,

[2] Australian Minesweeping And Surveillance System.

rather than simply calculating the distance between the Sweeper and Sweep and each mine at very small time increments, a more subtle method is used.

It is assumed that the Sweeper (and therefore the Sweep) speed is constant, so that given the whole set of tracks it is possible to calculate the time at which the Sweeper and Sweep pass each mine. These times are computed and stored prior to the start of the simulation. During the simulation, the sweeper takes large time steps, consistent with a smooth graphical display. Then the time taken from start of the sweep track is compared with the table of encounter times. When the times are close, the AMSG decides to assess the encounter, and it compares the y-axis displacements from the track, of the Sweeper and Sweep, with the mine. If these are within activation width A for the Sweep or Sweeper, and of the same sign, and the probability of actuation B is satisfied by comparing it with a random number, then it is assumed that :

> either the mine has been actuated without asset damage,
> the mine has actuated and damaged the Sweep, or
> the mine has actuated and damaged the Sweeper (MCMV).

A decision is then made as to which of these occurs, by determining if the Sweep and/or Sweeper is within the damage front F and if so, whether a random number is less than the damage probability BF. If it is, then the Sweep or Sweeper is taken as damaged (whichever is relevant). Otherwise, the mine is considered successfully swept.

This approach proved to be very efficient computationally, if somewhat more complex to program than a simple time stepping approach.

Mine counts and arm delays are also modelled. Mine counts, or ship counts, are the number of platforms detected by the mine, after arming, before it will actuate. Arm delay is the time after the start of the game at which the mine is 'armed' and will start counting down mine counts.

Arm delay is treated by comparing the mine delay for the mine under consideration (from elapsed times, as explained above) with the total time elapsed since the sweep run began. If the elapsed time exceeds the delay time for the mine, then it is assumed armed, and the y-position checks are made. If the y-location condition is satisfied, then the mine count is decremented. Each time a decrement is made, a check on the mine count is undertaken. Once this reaches zero, the mine is taken as exploded, and the consequences of that evaluated (no asset damage, damage to Sweep, or damage to Sweeper).

When no damage is done by an exploded mine (it is outside the damage radii, or did not satisfy the probabilities of damage to either asset), then a characteristic sound is produced, and the exploded mine symbol displayed. However, if the mine detonates within the Sweep or Sweeper damage radius, and the damage probability is also satisfied, then the appropriate asset damage statistic is advanced. A characteristic, different sound is made in each case, and the relevant damage symbol displayed at the location of the actuation.

3.2 Navigation Error

The MCMVs track is generated such that the vessel does not jump in y-position randomly, in an unrealistic fashion. The track the vessel travelled had to be

smooth and to appear continuous for the graphical display but at the same time it needed to produce a random distribution of a known type for use during assessment of mine encounters. The vessel's probability of location about the intended track is distributed normally in the long term, but wanders satisfactorily in the short term.

The method uses the notion of a random walk [3]. There is a finite probability of a y-displacement in position at each time step, and the probability of moving towards the intended track increases according to a Gaussian function as the vessel moves away from the intended track.

Assume that the probability at any location, of going right is p. Then the probability of going left is q=1-p.

AMSG assumes that the ship will with some probability (pdev) move left or right by a fixed distance at each time step. That is, if a random number is compared with pdev, and found to be larger, the vessel will stay on its present course. Otherwise, the following is used to determine whether the vessel moves towards or away from the track.

To simulate the motion of a ship following an intended track, the program generates a probability for the ship at position y as given by the Gaussian probability function,

$$p(y) = \exp\left[-\frac{1}{2}\left(\frac{y - y_{track}}{\sigma}\right)^2\right] \qquad (1)$$

A random number is generated (between zero and one). If this is less than p(y) the ship moves closer to the intended track, if it is greater than p(y) then the ship moves outward. The vessel is exactly on the track to start with and whenever it is exactly on track it will move randomly one step left or right.

The game computes the next y position as :

$$y_{new} = y_{old} + \text{sign}(R-p(y)).\text{sign}(y-y_{track}).y_{inc} \qquad (2)$$

where sign(y) is simply the sign of y, R is a random number between zero and one, and y_{inc} is the sideways step size.

The navigation error (deviation from track) is reset to zero at the start of each full circuit of the minefield. (A circuit is a complete set of tracks, the game allows circuits to be repeated).

3.3 *Arm Delay[3] and Ship Count*

The approach used to determine the mine arm delay and the mine ship count, is that used in the COGNIT code [2], [4], [5]. This assumes that these parameters are distributed according to a truncated geometric distribution. For ship counts, for example, the fraction of mines initially on ship count a is given by :

[3] Also known as arming delay.

$$f_o(a) = \frac{(1 - \beta)\,\beta^{a-1}}{(1 - \beta^{amax})} \qquad (3)$$

Here amax represents the maximum ship count, and beta is the geometric ship count distribution parameter. As noted in [2], "this parameter is a positive-valued input datum used to define the minefield characteristics. Note that when beta equals 1, $f_O(a)$ converges to 1/amax, for all values of a specifying a uniform ship count distribution. When beta is greater than one there is a greater proportion of mines with a high ship count setting. When beta is less than one but greater than zero, the fraction of mines with a low ship count setting is increased. For each mine, ship counts are selected by sampling uniform random number distributions as done in ref [4]."

The arm delay for each mine is determined in an identical manner. The distribution parameter for arm delay is usually denoted as gamma.

3.4 Control of the Simulation

The simulation is time stepped in a coarse fashion consistent with the requirements of the graphical display. Each track is arbitrarily divided up into 30 time steps. The total time for each track is given by the track length divided by the Sweeper speed. The time step is just 1/30 of this. Sweep-mine encounters are evaluated on the closest time step after the actual encounter time.

The track length is determined at run time by pointing the mouse cursor to the desired left hand starting point for the tracks. The right hand end of the track is fixed at the end of the field or channel, and cannot be changed, except by changing the field (channel) length.

Once the track length is set and the duration of travel on each track calculated, the time from the start of any right-directed track to reach each mine location is calculated, and stored (see section 3.1).

The player is given the option of resetting all exploded mines, by choosing Yes - reset mines to unexploded from the RESET THE MINES? Menu displayed at the start of a run. (The alternative is No - keep game data as is.) When the mines are reset, all mine counts go to their initial values (section 3.3), all mines are set to 'unexploded', and arm delays are set to their initial values.

If the mines are not reset, they are left in the condition they were in at the completion of the last game. (Because of this feature, several different tactics can be tried one after another on the same initial minefield).

The simulation will then proceed to run through the tracks set from the Tactics Menu, in sequence, with repeat track runs where specified, and at the completion of a full circuit, the code will repeat the circuit for the number of circuits specified. As each mine is encountered (section 3.1), the appropriate action is taken, and the relevant statistics (Mines Swept, Sweepers Lost, Sweeps Lost) incremented.

An estimate is made of the time left for the game, based on the total number of passes over each track, and the time per track. The Sweep/Sweeper turn time is accounted for in this calculation. The time simulated so far is also shown.

If the tracks have been set such that a track intersects the coastline at any time, an error message is displayed when the simulation reaches the point of the

MCMV going aground, and the game terminates. When this happens, the Player will need to change track spacings, offsets, or the left hand starting point.

The game, as written, does not terminate when a Sweeper or Sweep is lost. It places greater importance on assessing how good or bad the tactic is, rather than on simulating a real MCM operation. However, a run can be aborted manually following a sweeper sinking - as described in section 4.6 below.

4. *Details of the Program*

This section discusses the AMSG computer program, concentrating on the user interface.

Interaction with the program is by letter keys, arrow keys and return key, or mouse (details can be found in Appendix A). Some functions require the mouse (for example, laying a minefield), and the program will not run unless a mouse driver is present.

The use of the mouse to set parameters is somewhat unusual and a brief explanation follows. Suppose that the user wishes to change the Turn Time in the Sweeper Settings Menu. Select Turn Time, and a data change box is displayed. This box shows the current value set. This value may be altered by pointing the mouse to the Up or Down arrow shown on the base of the box, and clicking the left button. The set value will increment or decrement with each click of the left button. When the desired value is achieved, click the right button t. . urn to the menu. This process applies to all cases where a new value of a parameter is to be set. Note that the process can also be done with the arrow keys, in which case, hitting Enter will accept the new value and return to the menu.

The mouse may also be used whenever a Hit Any Key to Continue message is displayed. Use of the left button will allow the user to continue. Pressing the right button will usually abort the current process. For example, it will terminate a HELP display.

4.1 Sweep Settings

The Sweep settings are mostly set in the Interactions Menu, which is called from the Umpire Settings Menu. The relevant parameters are

characteristic actuation width, A (yds) (range 1-500)
characteristic actuation probability, B (range 0.0-1.0)
damage width, F (yds) (range depends on mine type)
damage probability, BF (range depends on mine type)

which all depend on the nature of both the Sweep and the threat mine(s).

Note that in the current approach, it is assumed that the mine interacts separately with both the Sweep and with the Sweeper. The game can use different A, B, F and BF values for the Sweep and for the Sweeper (MCMV).

The values used in the game can be altered by the Umpire. They are exactly the parameters used by the game simulation to determine the sweeping performance.

The values assumed by the Player might be different, and are not used by the game itself.

4.2 *Sweeper Settings*

The Sweeper, (the MCMV) is described in the same terms as the Sweep. That is, its parameters are mostly set in the Interactions Menu, under the Umpire Settings Menu. As for the Sweep, the parameters are :

characteristic actuation width, A (yds) (range 1-500)
characteristic actuation probability, B (range 0.0-1.0)
damage width, F (yds) (range depends on mine type)
damage probability, BF (range depends on mine type).

In addition, the Sweeper Menu, accessed from the Main Menu allows the setting by the Player of :

the Sweeper speed (which is also the Sweep speed) (range 0-50 kts)
the Navigation Error (range 0-500 yds)
the Tow Distance (range 0-5000 yds)
the Turn Time (range 0-500 mins).

All these parameters together completely characterise the MCMV. No provision is made for specifying a particular vessel by its class, or otherwise.

4.3 *Mine Types and Mine Settings*

Five mine types are built in to the code. These are intended to cover the main generic mine types. They are :

Coarse set ground
Medium set ground
Sensitive set ground
Anti-MCMV
Moored.

These mines are completely described in AMSG by the following set of parameters :

A, B, F, BF for mine vs Sweep and mine vs Sweeper
Mine count (the maximum count, and beta are specified)
Arm delay (the maximum delay, and gamma are specified)

The mine count and arm delay for individual mines in the field are computed from a geometric distribution, using the above parameters. The details are given in Section 3.3.

The mines in the minefield may be laid from the Umpire Settings Menu. This is done by selecting PLACE MINES. The chosen map (selected from NEW MAP, also in the Umpire Settings Menu) is displayed, and Umpires are asked to delineate the region in which to lay the mines. This region is demarcated by two vertical lines across the shipping route. The latter is shown by a brown horizontal line on the map, and cannot be changed.

The two vertical lines are set by pointing the mouse pointer and pressing the mouse left key. The lines appear on the map.

The mines can then be set within this region of the map. Umpires can use up to five different mine types. They are asked to nominate the number of mine types to lay, and then to select from a list, the specific types to use. In doing this, the characteristics of each mine type are displayed. If the Umpire wants to change the mine characteristics of a particular type, he may do so, by selecting the Mine Properties Menu and/or the Interaction Menu prior to placing the mines.

Once the Umpire has decided the number of types and the particular types of mines to lay, he is shown the minefield map, with the area to be mined delineated, and may place mines anywhere within the region he has selected. This is done by pointing to the desired location with the mouse, and pressing the left mouse button. When the Umpire is finished laying the first type of mine, he may select the next type by pressing the mouse right button. The colour of the mine symbol displayed on the screen will change when this is done, to confirm the new mine type. This may be done in series until the Umpire has layed mines of each type.

Up to 30 mines may be laid. Once 30 are in place, the screen changes, returning to the Umpire Settings Menu. The field can be inspected by selecting SHOW THE MINEFIELD.

Once finished with the Umpire Settings Menu, (and selecting QUIT), the Umpire is given the option of saving the minefield. If this is desired, all the map and minefield details are saved to a file. This has the extension *.MFD. The minefield file may use a previously used name (in which case the old data in that file is overwritten), or a new name. In any case the file extension will be MFD. There is no need to specify this extension, as it is automatically added.

If the Umpire chooses to save the minefield to a file, this may be recalled by the Player at any time, and used to play against. This is done by selecting the Options Menu, then RESTORE PREVIOUS GAME. The Player can then select the desired game from a displayed list of *.MFD file names.

4.4 Interaction Settings

These are set in the Interactions Menu, called from the Umpire Settings Menu. The interaction parameters A, B, F, BF are set, for both the interaction between the Sweep and a specific mine, and for the Sweeper and a mine (see sections 4.1, 4.2). Default values for these parameters are written in to the program, but this menu allows them to be changed. Altered values will be remembered by AMSG, provided the user saves the game on termination of minefield placement, on termination of a run, or unless RESET TO DEFAULT is selected from the Options Menu.

The default settings have no deep significance, and it is recommended that the Umpire use more realistic values by setting his/her own. They can only be changed by the Umpire.

4.5 *Tactics*

The Player can define the total number of tracks, then select each track in turn, and set its offset location relative to the centre of the channel, and also set the number of runs on that track.

Alternatively, he can assume all tracks have the same number of runs over them, and the same spacing exists between all tracks. He can then set a general track offset increment, and the general track offset maximum, so that any track offset is automatically set from the expression

$$\text{Offset} = (\text{Offset Increment}) * (\text{Track Number}) - (\text{Offset Maximum}). \quad (4)$$

Hence for tracks 'above' the centre line of the channel, the offset is positive, and for tracks 'below' the centre line it is negative.

A Player that chooses to set the tracks this way must also set the number of runs per track, which will be the same for all tracks.

Note that choosing Number of RUNS ON THIS TRACK greater than unity, will cause the runs on the designated track to be repeated before moving to the next track. Alternatively, choosing NO OF WHOLE CIRCUITS as greater than unity will cause the whole circuit to be repeated the chosen number of times.

The third alternative is to set the tracks locations 'Visually', that is, with the mouse cursor on the screen. This option is the most flexible, but requires some manual dexterity to lay tracks exactly where they are wanted. With this option, the player simply points to the location of the track with the mouse, clicks the left button, and a track will be added to the list. To have multiple runs on a track, the player must lay further tracks on top of the one already defined. The tracks will be swept in the order in which they are laid. To complete the track laying process, simply click the right mouse button.

4.6 *Running a Simulation and Aborting a Run*

A simulation run is invoked from the main menu. Section 3.1 describes some of the details of what is seen during a run.

A run of the game itself may be aborted at any time by simply hitting the Escape key, or alternatively, by clicking the right mouse button. When this is done, the run ceases. It is not possible to re-start an aborted run. The Player must start the game from the beginning. However, any mines that were exploded during the aborted run, will remain exploded unless the option RESET THE GAME - Yes is chosen at the start of the next run.

4.7 *Reviewing a Game*

When the Player has completed a game, the outcome may be viewed several ways. Firstly, the results are shown on the graphics screen at game termination. This shows the number of mines swept, the number of Sweepers and of Sweeps damaged, and the map shows the locations of all mines swept.

The missing information in this display is the number and locations of remaining mines in the field. This can be seen by an alternate screen. If the Umpire accesses the Umpire Settings Menu, the locations of all mines, both those swept, and those remaining can be shown. This is done by selecting SHOW THE MINEFIELD. This discloses the unswept mines by type, in the same manner as when the Umpire laid them. The statistics of mines found and damaged assets are also shown.

4.8 Default Values

The ranges of all parameters used by the game, along with default settings are given in Appendix B. As noted above, none of these default values has any significance, and the Umpire and Players should reset these as required, to ensure that they produce realistic results.

4.9 Help

Help is provided at each menu. Select HELP from the Menu, and a summary of what each menu selection does will appear. The HELP for the Main Menu gives other useful information, as well.

To abort HELP at any time, hit the Escape key, or the mouse right button. The Menu will then be restored. A listing of the contents of each HELP file is given in Appendix A.

4.10 Passwords

The game as-supplied has a default password. The password is used to gain access to the Umpire's Settings Menu. It is also used in the CHANGE PASSWORD selection of the Options Menu.

The password can, and should, be changed. This is done by typing in the old password, then presenting the new one. The latter is stored by the program, and remembered for subsequent runs. The default password is 'donald'.

The password comprises a six character code. Exactly six characters must be used. Only upper case characters are recognised.

Three incorrect characters are permitted before the game aborts the attempt.

4.11 Terminating Session with AMSG

When finished playing the game, before ending the session, the Player is presented with three options. These are RETURN TO THE GAME, SAVE THE RUN TO MCMStuff.INI, and QUIT WITHOUT SAVING.

The first of these returns the Player to the Main Menu, with none of the data altered.

The second does as it says. The data used for the game is saved. This includes not only the map and minefield location of all mines and types, their state - either

exploded, unexploded, destroyed a Sweep, or destroyed a Sweeper, as well as the tactics data, and all other relevant information. On starting up the game again, this data will be automatically loaded, and the game run again. The only thing which is not saved is the position of the Sweeper/Sweep at the termination of the game. This means that a new run of the same game will start with the first track each time, not from where it might have been terminated. A backup is made of the previous game, as MCMStuff.BAK.

If the user elects not to save the game, then the previously stored game is preserved, and the current game data is lost.

4.12 Quick BASIC Version versus Turbo Pascal Version

The version of AMSG reported here is written in Borland's Turbo Pascal. An earlier version of AMSG written in Quick BASIC (QB) in 1990 is available (known as AMSP, where the P stands for Program). The "game-like" features of the QB version are intended as an aid to its use in statistical studies, rather than as a desirable characteristic, and hence it is more difficult to use than the Turbo Pascal version. The Quick Basic version performs multiple monte-carlo simulations and collects statistics. It can automate the process of having three different types of sweepers pass over the minefield in succession but it only has one (laborious) method for specifying sweeper tactics, and cannot keep separate .MFD files, so it cannot store the current minefield state.

5. Conclusions

This paper has described a microcomputer mine sweeping simulation program in the form of a game.

AMSG is not intended to represent a definitive simulation of Mine Sweeping. Rather it illustrates a highly simplified form of the real-life situation. This is done in order to assist the Player attain an improved understanding of the consequences of each parameter change on the outcome of a Mine Sweeping operation or exercise.

While the AMSG has 'toy-like' qualities the reader should note that it demonstrates that simulation technology can become available at short notice to those being trained in mine warfare, and to those who will make decisions at a tactical or strategic level. The AMSG, or some program like it, can in future be useful for training or studies as part of a larger suite of programs possibly linked to a central repository of data. For example, a simple simulator could be built into the program suite of the Mine Warfare Systems Centre. The technique of Model Based Reasoning, currently being developed under the artificial intelligence banner, could use such a program as an aid to making decisions about tactics or equipment fits in the absence of a human player.

The AMSG cost very little to develop and yet covers a large number of tactical parameters.

5.1 *Improvements*

Because AMSG is a simplified representation of the real Mine Sweeping operation there are a number of ways that the game might be further improved. These are listed as follows.

Magnification of the Area of Operation to more realistically represent the scale of a likely minefield.

Inclusion of specific vessels, with the changes necessary to A, B, F and BF for particular mine types. For example, this might include an MHI, a MHC, a COOP SMALL and a COOP LARGE. A range of Sweep types could also be included.

More realistic maps, perhaps emulating navigational charts.

A non-linear channel (e.g. a 'dog-leg').

Facility for restarting the game from where it was interrupted.

Inclusion of an estimate of clearance level, based on Player-defined As and Bs, and the number of mines found so far.

Facility for multiple Players. This is partially implemented, as a number of Players can play on different machines, using the same Umpire-set minefield.

The ability to use the same mine with more than one distribution of Arm Delays and Ship Counts.

Some of these suggested improvements are more easily implemented in the structure of AMSG than others, but all are possible. A potential limitation on further improvements is the size of the code. It is currently contained in an executable file of size 105k bytes. If it is desired to make the game much larger, then conversion to an Object Oriented approach with greater use of dynamic memory is recommended. An alternative is to make use of overlaying techniques.

5.2 *Acknowledgments*

The authors would like to thank Dr Peter Ryan, Robert Dow and Kevin Gaylor for many useful discussions on MCM, which improved the quality of this work.

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Appendix A: Help File Contents

A.1 HELP for the MAIN MENU

The AMSG was designed and written in Central Studies Branch by Michael J.J. Harmer and Keith Lawson. The code has been translated into Turbo Pascal (Vers 6.0) at DSTO MRL Melbourne, Maritime Operations Division, and heavily modified. For details, contact Dr D.D. Richardson, (03) 246-8612.

A.1.1 To Make Selections From a Menu

If you have called up this help screen because you couldn't get past the main menu, what you have to do is use the arrow keys to go up and down the options (left and right). Pressing RETURN at the line you want will activate your choice. Alternatively or point to your choice with the mouse and press the LEFT button. You could also or type the highlighted character in the menu list. (Despite all these options a mouse MUST be connected - some other functions need it).

A.1.2 The Main Menu

RUN GAME	Watch the simulation.
NO GRAPHICS RUN	Run a game without animation. It is a bit faster.
SWEEPER MENU	This lets you change the characteristics of the sweeper. (Speed, nav error, tow distance, turn time).
TACTICS MENU	This lets you change the tactics of the sweeper. (Track spacing, number of runs per track).
UMPIRE MENU	This is where the Umpire sets up the minefield, defines the mine characteristics and the parameters of the interaction between the sweepers and the mines (ie A, B, F, BF). A PASSWORD IS REQUIRED FOR ACCESS.
OPTIONS	This allows you to reset the game dataset to the default values (which are not very useful), or set the minefield to one defined by the Umpire and stored in an *.MFD file.
HELP	If you're reading this then you know what it does. Hit the RIGHT Mouse Button during Help to return to the game.

QUIT	Stops the program. If you want, the set-up will be saved.

A.1.3 How the Game Works - 1 - Geography

The field you play the game on is rectangular. It has dimensions in nautical miles (or yards). You can change the size of the field under the TACTICS MENU choice in the Main Menu.

The field has a shipping channel marked by a brown line, at 10.0 nm from the bottom of the picture.

The game is played within an area of the screen marked by grey lines on the map. To observe this, try selecting the UMPIRE SETTINGS choice, then select SHOW THE MINEFIELD. You will see the map, and any mines already laid. You will also note the grey lines delineating the working area, and the brown shipping channel. The mine parameters, and the interaction data (A's and B's, etc) are also displayed for the programs "current" mine.

A.1.4 How the Game Works - 2 - Minefields

You can lay a minefield, or use a minefield supplied by umpires. To lay a field, you start by designating the area of the field that you wish to lay mines within. This is done by pointing the mouse at the x-axis location you want - left extremity first, then press the mouse LEFT button to select the location, then do the same for the right extremity.

Once you are satisfied with the minefield (or once someone else has set some mines for you), and also chosen the other mine and interaction parameters (these might have been set up by an umpire also), you can then either run the game as is (see the next page), or reset the tactics to your own choice by selecting TACTICS MENU.

You can abort the game running at any time by hitting the <Escape> key, or the mouse RIGHT button.

A.1.5 How the Game Works - 3 - Run the game

Selecting RUN GAME or NO GRAPHICS RUN at the main menu will run the game. The first thing to appear will be the SWEEP PLACEMENT Screen. This allows you to choose the starting point for the sweeper. Move the mouse to the point you want the sweeper to start from and press the LEFT mouse button.

The length of the swept channel is defined in the sweeper data area, and the width of the swept channel is a function of the sweeper tactics. The length of the sweep track is further limited to keep it within the working area of the game. The further right you set the starting point for the sweeper, the shorter the track length will be, for the same channel length.

You can observe the state of the minefield after a game by selecting Mine Settings, Show the Minefield (if you know the password).

A.2 Help for the UMPIRE MENU Choice

This is the menu where the Umpire can define some of the parameters of his/her minefield.

The AMSC allows the miner to lay five types of mines -

Coarse set ground mines
Medium set ground mines
Sensitive set ground mines
Anti-MCMV ground mines
Moored mines

The mine/sweeper interaction is set from the INTERACTION MENU choice. The Channel Length and Width may also be changed. So may the map of the land area to use.

The UMPIRE MENU has these items

MINE PROPERTIES	This calls the menu from which you can set the mine properties, such as type, max counts, max arm delay, beta AND gamma.
SHOW THE MINEFIELD	This displays the map and shows all mines currently laid, as well as those already exploded. It also shows mine and interaction parameter settings.
PLACE MINES	This brings up a couple of screens which are used to lay mines (more details, below).
INTERACTION MENU	Here you can set the A's and B's for interaction between the mine, the sweep and the sweeper.
CHANNEL LENGTH	Set how long the swept channel is (max 30,000 yds).
CHANNEL WIDTH	Same thing for the width (max 20,000 yds).
NEW MAP	Lets the Umpire set different map. Maps are made using program ®MakeMap, and stored in *.MAP files. To load a map, select one from the list displayed, or select NEW NAME and type in the path and file.
HELP	This is it
QUIT THIS MENU	Go back to the Main Menu. If you have set any new data, you will be able to save it as a *.MFD file, with a name either selected from the existing list, or given by you.

A.2.1 Using PLACE MINES

WARNING : If you choose PLACE MINES, all currently laid mines will be deleted. You start the minefield again.

You begin by specifying how many mine types you intend to lay. Then you say what type of mine each one is. If you select three mine types, then you are asked to select the type of mine 1, mine 2 and then mine 3 from the five types available. For example, you might say that you are going to lay two mine types, the first being Moored mines, the second type being Sensitive Set Ground.

(The mine/sweeper interaction information is set under the UMPIRE MENU).

When mine selection is done, you see the first mine placement screen.

A.2.2 The Mine Placement Screens - 1 - The Place Mine Area Screen

In this screen you are asked to provide two points along the shipping route, the miner lays mines between these points in the following Place Mines Screen.

Select two points along the shipping route by clicking the LEFT mouse button.

The screen will disappear when you have selected the second point. It will be replaced by the minelaying screen.

A.2.3 The Mine Placement Screens - 2 - The Mine Laying Screen

This lets you place mines in the area selected in the PLACE MINE AREA Screen. Up to 30 mines may be laid, in total.

To lay a mine of the current type :-

> Move the mouse to the point you wish to lay the mine.
> Click the LEFT mouse button.

To move from one mine type to the next, press the Right Mouse Button once. The mine colour will change, and you can proceed to lay the next mine type.

To leave this screen when you have finished laying mines :-

> Click the RIGHT mouse button, the pointer should disappear, or
> Press the ESCAPE key. You will return to the Main Menu.

A.3 Help for the SWEEPER Menu

The Sweeper Menu lets you define some of the data about the sweepers. AMSG does not allow you to set the Sweeper type (eg MSA(S) or MSA(L)) explicitly. You set up the Sweeper characteristics.

The parameters for the interactions between the sweepers and the mines are entered via the INTERACTION SubMenu, under the UMPIRE's Menu.

The SWEEPER Menu is used to enter the basic sweeper data:-

SWEEPER SPEED	Sweeping speed in knots (max 50!)
NAV ERROR	Standard Deviation of the NAV error in yards (max 500)
TOW DISTANCE	Sweeper to sweep separation in yards (Max 5000)
TURN TIME	Turn time in minutes (max 500)
HELP	This is it
QUIT THIS MENU	Return to Main Menu

A.4 Help for the TACTICS Menu

This menu allows you to put in the number of runs per track and the track spacings for the sweeper. The menu allows three ways of defining the sweeper tracks, plus a few utility features.

The first method of putting in the sweeper tracks is very precise, but also very long winded.

The sweeper tracks for a particular type are defined as -

> Number of individual tracks
> *and for each individual track*
> Track Offset (from the centre of the swept channel) and
> Number of runs on the selected track

The second method for putting in the tracks can be related easily to the progressive sweeping tactic modelled in COGNIT. You can set :-

> Number of individual tracks
> General Track Offset Increment (between adjacent tracks) in yds
> General Track Offset Maximum, also in yds
> Number of circuits

Tracks are spaced evenly, track position is defined by,

> Offset = (Offset Increment)*(Track Number) - (Offset Maximum)

"Track Number" goes from 1 up to "Number of Tracks". Thus the distances of the furthest tracks in each direction from the shipping route are at -

> M: (Offset Increment) - (Offset Maximum), and
> N: (Offset Increment)*(No of Tracks) - (Offset Maximum).

This method defines a circuit of tracks which can span the shipping channel.

Alternatively, you can select VISUALLY SET TRACKS. Then you can set the tracks anywhere you like, by pointing to the locations of your choice with the mouse, and clicking the Left Button. Clicking the Right Button will terminate your input. The circuit is defined by the tracks in the order that they are entered with the mouse. The number of circuits must also be defined.

The TACTICS MENU has the following options

NUMBER OF TRACKS	The number of individual tracks for the ship (max 50).
NUMBER OF THIS TRACK	The track number that the offset and number of runs (next two items) refer to.
SPECIFIC TRACK OFFSET	The track offset for this track number (max 2000 yds).
NUMBER OF RUNS	The number of runs for this track number (max 50).
GENERAL TRACK OFFSET INCREMENT	In yards (max 2,000).
GENERAL TRACK OFFSET MAXIMUM	In yards (max 10,000).
VISUALLY SET TRACKS	Use the mouse to set tracks in desired positions and number of repeats.
NUMBER OF CIRCUITS	The number of times that the ship will repeat all the tracks (max 50).

The tactics menu also has several utility items :-

SUGGEST As AND Bs	This gives you estimates of A, B, F and BF for the Sweeper and the Sweep. You can use these to estimate your track spacing and runs per track, using Cognit or ATP-6, for example. Then put these values into AMSG and see how well you did.
SHOW THE TRACKS	Lets you see where the tracks are currently set.
HELP	This is it.
QUIT THIS MENU	Return to Main Menu.

A.5 Help for the INTERACTION Menu

As this menu is called from the Umpire Menu, you need to have the password to be able to change the interaction parameters.

This is where data can be put in about the INTERACTION between the sweepers and the mines. Remember that AMSG has five types of mines so there's quite a lot of data. It is in the form of actuation and damage widths and characteristic probabilities for sweep versus mine and sweeper versus mine.

The AMSG should remember any changes you make, (if you request it) but the data that comes with the AMSG when it is new is unclassified test data. Users can put in more realistic data for their own use. Data is defined for the SWEEPER/MINE interaction and the SWEEP/MINE interaction. AMSG V1.2 assumes that if a sweep sets off a mine it will not damage the sweeper and vice versa.

The choices in the INTERACTION menu are :-

MINE TYPE	Selects the mine type (also settable in the Mine Properties Menu)

And for the selected combination ... (All these numbers change when you select a different mine type) ... you see two sets of numbers :-

A	Characteristic actuation width in yards (range 1 - 500).
B	Characteristic actuation probability (range 0.0 - 1.0).
F	Damage width in yards (F < A).
BF	Damage probability (BF < B).

These are for the SWEEPER/MINE and SWEEP/MINE interaction and work the same way as those in ATP-6B and COGNIT except for the differentiation between SWEEPER and SWEEP.

A.6 Help for the OPTIONS sub-menu

This is the menu where you can reset the password, reset the game parameters to the benchmark data, or revert to the previous game data. You may choose :-

NEW MINEFIELD	Allows you to load up a minefield previously laid by the Umpire. These are stored .MFD files.
CHANGE PASSWORD	Allows you to define a new password (6 chars). You MUST know the old password to define a new one. If you change password, the game data will be automatically saved.
RESET TO DEFAULT	This sets all the data to the default values. After this, you will find that no mines are laid.
RESTORE PREVIOUS GAME	When you Save, on exit from AMSG, a back-up is made. You can swap the current game data with the back-up data, by selecting this option.
HELP	This is it.
QUIT THIS MENU	Go back to the Main Menu.

A.7 Help for the MINE PROPERTIES menu

This is the menu where the Umpire can define some of the parameters of the mines. The AMSG allows the miner to lay five types of mines :-

Coarse set ground mines
Medium set ground mines
Sensitive set ground mines
Anti-MCMV ground mines
Moored mines

In the MINE PROPERTIES menu you may set up the maximum ship count and arming delay for each mine type. Also you can set the associated values of beta and gamma.

The MINE PROPERTIES menu contains :-

MINE TYPE	This selects the mine type. You have a choice of five types.
MAX COUNT	This sets the maximum ship count (max 50).
ARM DELAY	This is the maximum arming delay and is measured from the time that the sweepers start operating in hours (max 20.0).
BETA	This parameter defines the distribution of ship counts, a BETA near 0 means that most are on count 1, a BETA near 10 means most are on the maximum count, a BETA of 1 means that the counts range uniformly from 1 to the maximum (max 10.0).
GAMMA	This defines the distribution of arming delays, it works the same way as BETA (max 10.0).
HELP	This is it.
QUIT THIS MENU	Go back to the Umpire's Menu.

Appendix B: Default Parameter Values, and Allowed Ranges

The following gives the default values of parameters used in AMSG, along with the allowed ranges of these parameters, if reset. There is no particular significance to the values assigned as defaults. The user should set his/her own, more realistic values.

B.1 Run Control, Sweeper and Sweeper Track Defaults

Parameter	Default	Range	Meaning
NumSimulations	1	(QB version variable)	Number of repeat simulations
NumOfTracks	19	1-50	Number of tracks
NumOfThisTrack	1	1-NumOfTracks	Designated track number
Offset	100	-2,000 - +2,000	Distance between tracks (yds)
MaxOffset	900	-10,000 - +10,000	Distance of furthest track from channel centre (yds)
NumOfRuns[I]	1	1-50	Number of runs on track I
NumOfCircuits	3	1-50	Number of times circuit is repeated
MTy	1	1-5	Mine type number
FieldL	5,000	250 - 30,000	Field length (yds)
FieldW	2,000	250 - 50,000	Field (channel) width (yds)
Sigma	10	1-500	Navigation error (yds)
V	7	1-50	Sweeper speed (kts)
TT	15	1-500	Turn time at end of track (mins)
TowDistance	1,000	0-5,000	Separation between Sweeper and Sweep (yds)
TypesLaid	1	1-5	Number of mine types laid

B.2 Mine Characteristics and Interaction Data.

B.2.1 Type Numbers

Type number	Mine Type
1	Coarse Set Ground
2	Medium Set Ground
3	Sensitive Set Ground
4	Anti-MCMV
5	Moored

B.2.2 Default interaction data

Type	MCMV A	Sweep A	MCMV B	Sweep B	MCMV F	Sweep F	MCMV BF	Sweep BF
1	80	140	0.45	0.92	56	30	0.4	0.6
2	140	300	0.92	0.8	56	30	0.5	0.6
3	80	140	0.5	0.92	56	30	0.45	0.6
4	60	80	0.1	0.4	56	30	0.05	0.24
5	10	5	0.25	0.01	10	2	0.24	0.01
range	1-500	1-500	0-10	0-10	1-A	1-A	0-B	0-B

B.2.3 Arm delay and ship count

Mine Type	Max Count	Beta	Max Arm Delay (days)	Gamma
1	10	0.8	5	0.8
2	10	0.8	5	0.8
3	2	0.8	0.5	0.8
4	2	0.8	1	0.8
5	1	0.8	0	0.8
range	1-50	0.0-10.0	0-20	0.0-10.0

B.3 Program Constants

Parameter	Value	Meaning
MaxNumTracks	50	Max number of tracks
MaxNumberOfMines	30	Max number of mines
MaxNumOfTypes	5	Maximum number of different mine types
yRoute	10.0	Location of shipping route, in nautical miles
NoXPoints	30	Number of time steps on each track
IncFract	0.1	Navigation error fraction of sigma for a side step
pdev	0.3	Navigation error probability of deviating from a straight course

Appendix C: Creating Maps

Maps other than the current map may be read in from the Umpire Settings Menu, and selecting New Map. This allows the selection of a map for the display, from a list of maps already defined. These are found in files with the extension *.MAP. The map may be changed at any stage, simply by loading a new one. The new map is saved as the default at the end of a run.

New maps may be created by using the MakeMap utility provided on the AMSG program disk. The map is created by using the mouse to define the points delimiting the map's coastline. Simply place the mouse cursor at the location for the next point on the map, and press the left button. Pressing the right button will terminate the map outline. The left hand side of the map is always defined as land, and the map is drawn starting at the top left hand corner, and moving eventually to the bottom right hand corner. The last point on the map, defined by the mouse is automatically 'closed' with the point at the bottom left hand corner, so the map forms a single closed area of land.

New maps created in this way may be placed over old maps in an existing file, or written to a new (user defined) map name. If an old map is overwritten, the old map is backed up to a *.BAK file.

The help file for the Map Maker program is reproduced in the next section.

C.1 HELP for the MAIN MENU of the AMSG Map Maker V1.0

This is a support program for AMSG. It allows you to generate new maps to use with the game.

You do this by using the mouse to define the points outlining the coastline. You point to the desired positions sequentially, and hit the Left Button on the mouse to set the points, in turn.

When you have all the points you want, just hit the mouse Right Button.

Choose from the menu by either pointing with the mouse and pressing the Left Button, or by using the up and down arrow keys to select a line, then press <Enter>.

The map has the shipping route always shown in red. This is placed in the centre of the map. The map should be drawn so that it places the shipping route in the desired location.

The Menu allows you a choice of functions

SHOW MAP	Displays thee map currently in the system
NEW MAP	Allows you to draw a new map. The border will be shown as you define it. The first two points are always the two lefthand corners of the map region. 100 points may be set.
READ MAP	Lets you read in a map from a map file from disk.
SAVE MAP	Lets you save the map you have drawn in a file. You can choose from a list of existing file names, or add a new one. All map files have the .MAP extension.
HELP	This is it. Hitting the mouse Right Button during Help sends you back to the program straight away
QUIT	Stops the program. If you choose, the map can be saved in a file.

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ABSTRACT

This Note describes the Australian Mine Sweeping Game (AMSG). The game represents minesweeping and enables MCM officers to become more familiar with the consequences of various sweeping tactics. The game is designed for a single Player (or a team of Players working together) and an Umpire. The Umpire can lay a minefield, selecting mines from a list of five types. The scene can be set for the Players, and their performance monitored. The Players appraise the situation, and then devise the tactics for sweeping the minefield. Hints are provided on likely mines in the field. The game will show the Players how effective the tactics they chose proved to be, by showing a simulation of the minefield being swept.

The Australian Mine Sweeping Game

K.R. Lawson and D.D. Richardson

(MRL-TN-659)

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